

**METHOD TO MAINTAIN ORDER BETWEEN MULTIPLE QUEUES WITH
DIFFERENT ORDERING REQUIREMENTS IN A HIGH FREQUENCY SYSTEM**

BACKGROUND OF THE INVENTION

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Field of the Invention

The present invention relates generally to the operation of multiple command queues and, more particularly, to queue ordering and execution with multiple interdependent
10 queues.

Description of the Related Art

Within a variety of computer architectures, there are a variety of devices that utilize command queues. A command
15 queue is memory device that stores execution commands. For example, Direct Memory Access (DMA) devices are notorious for utilizing command queues.

Typically, commands are forwarded to some device, such as a DMA device, for execution. However, due to system
20 constraints, such as available communication channels, all the commands cannot be instantaneously and simultaneously executed. Instead, the commands are forwarded to a pipeline of the device for execution. The device then stores the commands in a command queue and eventually executes the
25 commands.

There are a variety of manners to execute the command, which can vary. Two common methods of addressing the order

of execution are to use strict ordering or to use stack down ordering. With strict ordering, commands are executed strictly on the order upon which the commands enter the command queue. For example, a store queue for a DMA module
5 would likely use strict ordering. With stack down ordering, commands can, not only, be executed in the order in which the commands enter the command queue, but also from the middle of the queue. Stack down ordering is often desirable in situations where there is interdependency between
10 commands in a given command queue. For example, a read command for a DMA module would likely use a stack down order.

Moreover, in a device that has a command queue, there may not necessarily be a single command queue. For example,
15 a DMA module can have separate queues for both storing and reading. A problem can arise with the order of execution, though, if there are two or more queues. There can be cases where there is cross-dependency between commands of different command queues. In other words, there can be a
20 first commands in one queue that requires execution of a second command in a second queue before execution of the first command. For example, in DMA device, if command 8 in the storage queue requires execution of command 4 in the read queue before the execution of command 8, then there is
25 interdependency between the storage and the read queue.

In most cases, though, each command queue is distinct. In other words, each queue tracks the commands and executes each command according to the requirements within the queue. However, there are some cases where interdependencies
5 between multiple queues exist. Typically, there is not an efficient technique or apparatus to track the order of execution and interdependencies across multiple queues.

Therefore, there is a need for a method and/or apparatus for tracking commands across multiple command
10 queues that addresses at least some of the problems associated with convention methods and apparatuses associated with the operation of multiple command queues.

SUMMARY OF THE INVENTION

15 The present invention provides a method for entering at least one command into a plurality of command queues. A command queue of the plurality of command queues at least corresponds to the at least one command is determined. The
at least one command into the command queue that corresponds
20 is entered. Upon entering the at least one command, a snapshot of the order of each of the plurality of command queues is taken. A valid bit is updated to indicate that a queue location is valid. A determination is made whether the command is dependent on any other commands to indicate

if dependencies exist. If any dependencies exist, at least one dependency in a dependency bit is updated.

BRIEF DESCRIPTION OF THE DRAWINGS

5 For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURE 1A is a block diagram depicting a stack down
10 queue command;

FIGURE 1B is a block diagram depicting a strict queue command;

FIGURE 2 is a block diagram depicting a multi-queue system;

15 FIGURE 3 is a flow chart of the entrance of a command into the multi-queue system; and

FIGURE 4 is a flow chart of command execution of the multi-queue system.

20 DETAILED DESCRIPTION

In the following discussion, numerous specific details are set forth to provide a thorough understanding of the present invention. However, those skilled in the art will appreciate that the present invention can be practiced
25 without such specific details. In other instances, well-

known elements have been illustrated in schematic or block diagram form in order not to obscure the present invention in unnecessary detail. Additionally, for the most part, details concerning network communications, electro-magnetic
5 signaling techniques, and the like, have been omitted inasmuch as such details are not considered necessary to obtain a complete understanding of the present invention, and are considered to be within the understanding of persons of ordinary skill in the relevant art.

10 It is further noted that, unless indicated otherwise, all functions described herein can be performed in either hardware or software, or some combination thereof. In a preferred embodiment, however, the functions are performed by a processor such as a computer or an electronic data
15 processor in accordance with code such as computer program code, software, and/or integrated circuits that are coded to perform such functions, unless indicated otherwise.

Referring to FIGURE 1A of the drawings, the reference numeral 100A generally designates a block diagram depicting
20 a stack down queue command. The stack down queue command 100A comprises a command 110, a validation bit 120, and identification (ID) bit 130, and dependency bits 140.

There are a number of features that have been incorporated into the stack down queue command 100A that
25 allow for efficiently operating and managing commands across

varying queues in a multi-queue system. The command 110 is configured to be the instruction, which can be a variety of instructions that the multi-queue could utilize. For example, the command 110 can require that address
5 XXXXX-XXX-XX be read. The validation bit 120 indicates that the command in the specified queue location is valid. In other words, the validation bit 120 identifies that the queue location contains a valid operation. The validation bit 120 can be used to determine if an older entry has
10 become invalid allowing the stack down queue to move to the older command and can assist in identifying dependencies. The ID bit 130 is a reference bit. The ID bit 130 relates the moving queue entries to outside entries. More particularly, the ID bit 130 allows the strict order queue
15 to track a command for monitoring any dependencies. The dependency bits 140 reference all of the bits that the command 110 is interdependent. In other words, the dependency bits 140 reference all other commands that are to be executed prior to the execution of the command 110.
20 There are a variety of manners to order the referencing data.

Referring to FIGURE 1B of the drawings, the reference numeral 100B generally designates a block diagram depicting a strict order queue command. The strict order queue
25 command 100B comprises a command 112, a validation bit 122,

and dependency bits 142.

There are a number of features that have been incorporated into the strict order queue command 100B that allow for efficiently operating and managing commands across
5 varying queues in a multi-queue system. The command 112 is configured to be the instruction, which can be a variety of instructions that the multi-queue could utilize. For example, the command 112 can require that address
XXXXXX-XXX-XX be read. The validation bit 122 indicates that
10 the queue location is valid. In other words, the validation bit 122 identifies that the queue location contains a valid operation. The validation bit 122 typically can assist in identifying dependencies. However, the validation bit 122 in a strict order queue does not utilize the validation bit
15 122 to move to the oldest command since the strict order queue cannot execute out of order. The dependency bits 142 reference all of the bits that the command is interdependent. In other words, the dependencies bit 142 reference all other commands that are to be executed prior
20 to the execution of the command 112. There are a variety of manners to order the referencing data.

Referring to FIGURE 2 of the drawings, the reference numeral 200 generally designates a block diagram depicting a multi-queue system. The multi-queue system 200 comprises a
25 unit pipeline 202, a stack down queue 220, and a strict

order queue 210. Also, there can be a single or multiple queues, as depicted in FIG. 2. Moreover, the queue can be of a variety of types including, but not limited to, strict order queues and stack down order queues.

5 However, an illustration of the general components of the multi-queue system 200 does not lend itself to a complete explanation of the multi-queue system 200. The stack down order queue 220 further comprises a plurality of stack down command entries 222, 224, 226, 228, and 229.
10 Each of the stack down command entries 222, 224, 226, 228, and 229 are a stack down queue command 100B of FIGURE 1A because the stack down queue command 100A of FIG. 1B each have an ID bit 130 of FIG. 1A that allows for accounting of the command which further allows for the execution of
15 command from the middle of the queue.

 The strict order queue 210 operates differently from the stack down order queue 220. The strict order queue 210 further comprises a plurality of strict order command entries 211, 213, 215, 217, and 219, a newest entry pointer
20 212, and an oldest entry pointer 214. Because the strict order queue 210 does not allow for the execution of commands from the middle of the queue, there is no need for the use of an ID bit 130 of FIGURE 1A associated with the stack down order command 100A. Instead, the strict order queue command
25 associates the oldest entry pointer 214 with the oldest

command, which is typically the next command in the strict order queue to be executed. The newest entry pointer 212 assists in maintaining an accounting of the overall order of the strict order queue 210 by indicating the next strict order queue location to occupy.

Referring to FIGURE 3 of the drawings, the reference numeral 300 generally designates a flow chart depicting the entrance of a command into the multi-queue system.

In steps 302, 304, 306, and 312, the command enters the unit pipeline and is directed to the correct, corresponding queue. Based on the nature of the command, the correct queue can be determined. There can be a single or multiple queues as shown in FIGURE 3. FIG. 3 depicts only the usage of a stack down queue and of a strict order queue for the purposes of simplicity of illustration. However, there can be a single or multiple stack down queues, single or multiple strict order queues, or any combination thereof.

In step 308, if the command belongs in the stack down queue, then the command is entered into the queue and, upon entry, a snapshot of the opposing strict order queue is taken. The snapshot of the strict order queue preserves the order of the strict order queue. Preservation of the order of the strict order queue allows for the preservation of the correct order of execution of command from either queue taking into account inter- and cross-dependencies.

In step 310, once the snapshot of the order of the strict order queue, then the new command is updated. The various bits, such as the validation bit 120 of FIGURE 1A and the dependency bit 140 of FIG. 1A, can be updated to reflect the status of the strict order queue and the status of commands internal to the stack down queue. Reflection of the order of the strict order queue allows for the proper execution of commands from taking into account inter- and cross-dependencies between the new command and existing commands in the strict order queue and stack down queue.

In step 314, if the command belongs in the strict order queue, then the command is entered into the queue and a snapshot of the opposing stack down queue is taken. The snapshot of the stack down queue preserves the order of the stack down queue. Preservation of the order of the stack down queue allows for the preservation of the correct order of execution of command from either queue taking into account inter- and cross-dependencies.

In step 316, once the snapshot of the order of the strict order queue, then the new command is updated. The various bits, such as the validation bit 120 of FIGURE 1A and the dependency bit 140 of FIG. 1A, can be updated to reflect the status of the stack down queue and the status of commands internal to the strict order queue. Reflection of the order of the strict order queue allows for the proper

execution of commands from taking into account inter- and cross-dependencies between the new command and existing commands in the strict order queue and stack down queue.

Referring to FIGURE 4 of the drawings, the reference numeral 400 generally designates a flow chart depicting command execution of the multi-queue system.

In step 410 and 420, the next valid command is found and executed. Based on the problems of inter- and cross-dependencies, the command can be require to be executed in a certain order. With the introduction of validation 120 of FIGURE 1A and 122 of FIGURE 1B and dependency bits 140 of FIG. 1A and 142 of FIG. 1B, the device that utilizes the multiple command queues can make a determination of the next command that can be executed.

In steps 430 and 440, a retire signal is generated, and the corresponding dependency bits and the validity bits are updated. Once a command has been executed, the inter- and cross-dependencies can change. Also, the order of execution requires updating.

In the strict order queue, the oldest entry pointer 214 of FIGURE 2 would have pointed to the executed command. Any commands that depend on the executed command have their corresponding dependency bits reset. Also, the validation bit for the retired entry would be cleared. This process

can continue until all queues are empty and have no outstanding commands to be executed.

In the stack down queue, it is not necessarily to oldest entry bit that is executed. Therefore, when a
5 command is executed, the information from the ID bit of the executed command can be utilized to clear corresponding dependencies within the entire multi-queue system. Also, the valid bit of the executed command is cleared so the next command entry can occupy the queue location. This process
10 can continue until all queues are empty and have no outstanding commands to be executed.

It will further be understood from the foregoing description that various modifications and changes can be made in the preferred embodiment of the present invention
15 without departing from its true spirit. This description is intended for purposes of illustration only and should not be construed in a limiting sense. The scope of this invention should be limited only by the language of the following claims.